Flagship Concepts for Astrobiology at Enceladus

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Data returned from *Cassini* indicate that Enceladus, a moon of Saturn, has a subsurface liquid water ocean. Simple and complex organics were detected amongst the water ice and vapor plume material (Waite et al. 2009; Postberg et al. 2018; Khawaja et al. 2019). The presence of salts (Postberg et al. 2011), nearly pure silica nanograins (Hsu et al. 2015), and molecular hydrogen (Waite et al. 2017) in the plume suggests that the ocean is geochemically interacting with a rocky core generating chemical disequilibria or sources of metabolic energy akin to the activity that sustains chemosynthetic ecosystems at Earth's seafloor.

This NASA-funded planetary study is designed to investigate large-sized mission concepts that can search for evidence of life in Enceladus's ocean through analysis of plume materials in space or on the surface. The goal is to provide the next U.S. National Academies' Planetary Decadal Survey with a quantified understanding of the science return of Enceladus life detection flagship-class mission architectures sufficient to consider prioritization relative to other exploration targets. Our study is considering three mission architectures: an orbiter, a lander, and a combination orbiter + lander. Each would address the following science goals: 1) Search for evidence of life; 2) Quantify interior habitats; and 3) Determine ejection mechanisms to understand the changes undergone by the samples between their synthesis and their collection. A key outcome of our study will be an understanding of the science returns for each of these architectures and the key trades between them.

To evaluate these mission architectures, we have categorized and prioritized the science objectives that respond to the science goals. We have translated these science objectives into sampling and payload requirements, prioritizing a suite of instruments that would look for chemical biosignatures for life detection and geophysical instrumentation for the contextual science objectives.

We are currently evaluating the trades associated with the payloads supported by various architectures. An orbiter would focus on sampling the plume as it flies through at altitudes 20-60 km from Enceladus's surface and velocities as slow as < 1 km/s, much slower than Cassini's. Both orbiter and lander concepts leverage recent NASA investment in technologies suitable for surface science at Europa (e.g. ICEE-2 and SESAME programs), but the more radiation-benign Enceladus environment (<6 mW/m^2) reduces the need for radiation shielding. A landed architecture will address sampling strategy trades to determine whether it is best to scoop or catch plume fallout. Our study will determine the maximum science return per dollar for each flagship architecture.

The Cassini-determined habitability of Enceladus's ocean and the ease of access to the samples from the plume makes a pressing case for exploring Enceladus in the next decade. The plume is active now and has been since at least Voyager; a return to Enceladus as soon as possible will advance the goal of detecting life beyond Earth, perhaps to a successful conclusion.

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